

Assessing the contribution of sea surface temperature and salinity to coral $\delta^{18}\text{O}$ using a weighted forward model

Kaleb A. Horlick^{a,b}, Diane Thompson^{c,d}, David M. Anderson^e

^a University of Colorado- Boulder, ^b NOAA World Data Center for Paleoclimatology, ^c Boston University, ^d National Center for Atmospheric Research, ^e Monterey Bay Aquarium Research Institute

1 Background

Accurately forward modeling the $\delta^{18}\text{O}$ of corals is critical for assimilating paleo-proxy data and climate models in synthesis efforts such as NOAA's Last Millennium Reanalysis (LMR). Thompson et al. 2011^[1] improved upon the univariate sea surface temperature (SST)-based linear regression forward model for coral $\delta^{18}\text{O}$ with the contribution of a bivariate version, incorporating sea surface salinity (SSS). Our work doubles the previous sample network size (n=45) and confirms the skill of the bivariate model. It builds upon other work^[2] that –at one site- extrapolated the relative contributions of SST/SSS to the coral $\delta^{18}\text{O}$ signal by added a weighting coefficient to each of the terms and optimizing the fit (r) between the coral $\delta^{18}\text{O}$ and the psuedocoral $\delta^{18}\text{O}$ ($\delta^{18}\text{O}_p$).

2 Methodology

-Univariate FM (UM):

$$\text{Psuedocoral } (\delta^{18}\text{O}_p) = a_1 * \text{SST}$$

-Bivariate FM (BM):

$$\delta^{18}\text{O}_p = (a_1 * \text{SST}) + (a_2 * \text{SSS})^{[1]}$$

-Weighted Bivariate FM (WM):

$$\delta^{18}\text{O}_p = \%_1(a_1 * \text{SST}) + \%_2(a_2 * \text{SSS})^{[2]}$$

Where a_1 is the species-dependent experimental & theoretical dependence of oxygen isotopic equilibrium on the temperature of carbonate formation^[3], a_2 corresponds to published basin-scale $\delta^{18}\text{O}_{\text{sw}}$ vs. SSS regression estimates^[4], and $\%_1$ and $\%_2$ are relative weighting coefficients varying from 0% to 100% by .5% steps taken to be representative of % contributions of SST and SSS to the $\delta^{18}\text{O}_p$ ^[2].

Only Tropical Pacific coral sites with a minimum of annual resolution and at least 30 years of calibration overlap were used. NASA GISSTemp and Delcroix (2011) gridded SST and SSS products were used for instrumental data.

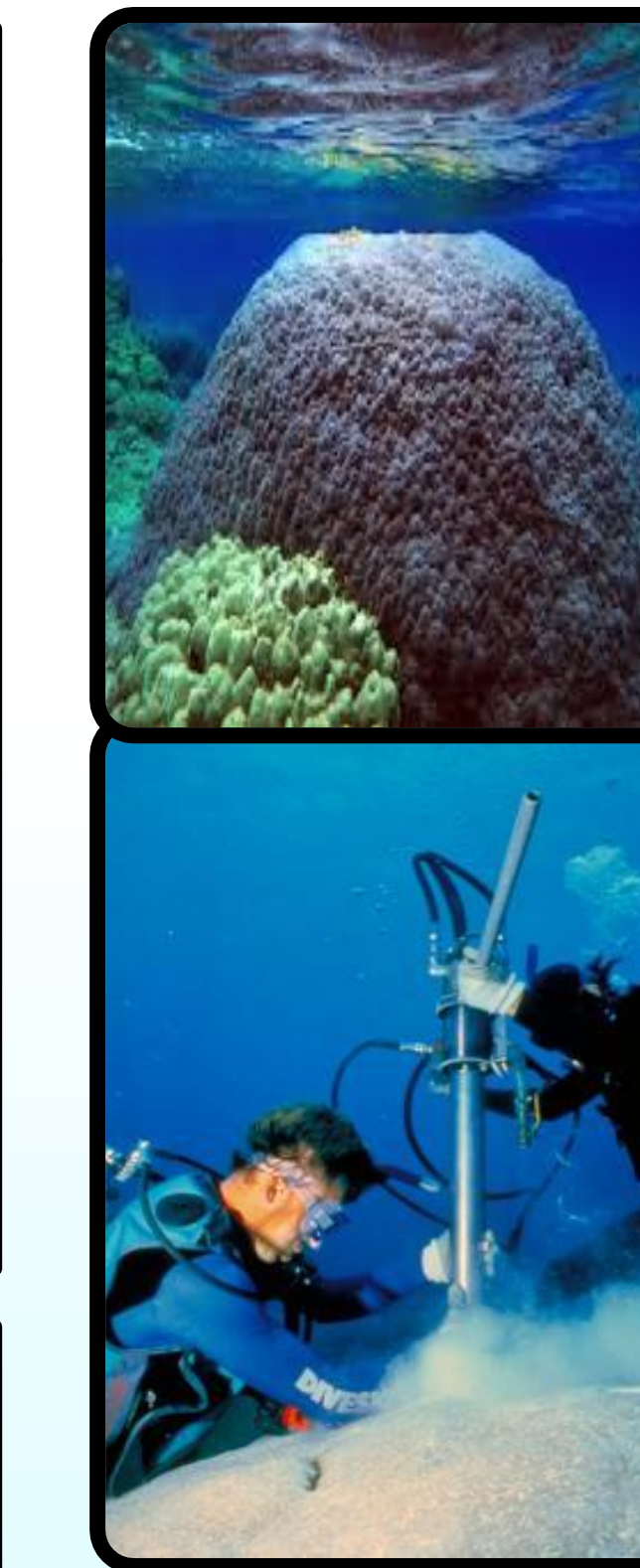


Figure 3: Sites where Weighting Method Optimizes Bivariate Model

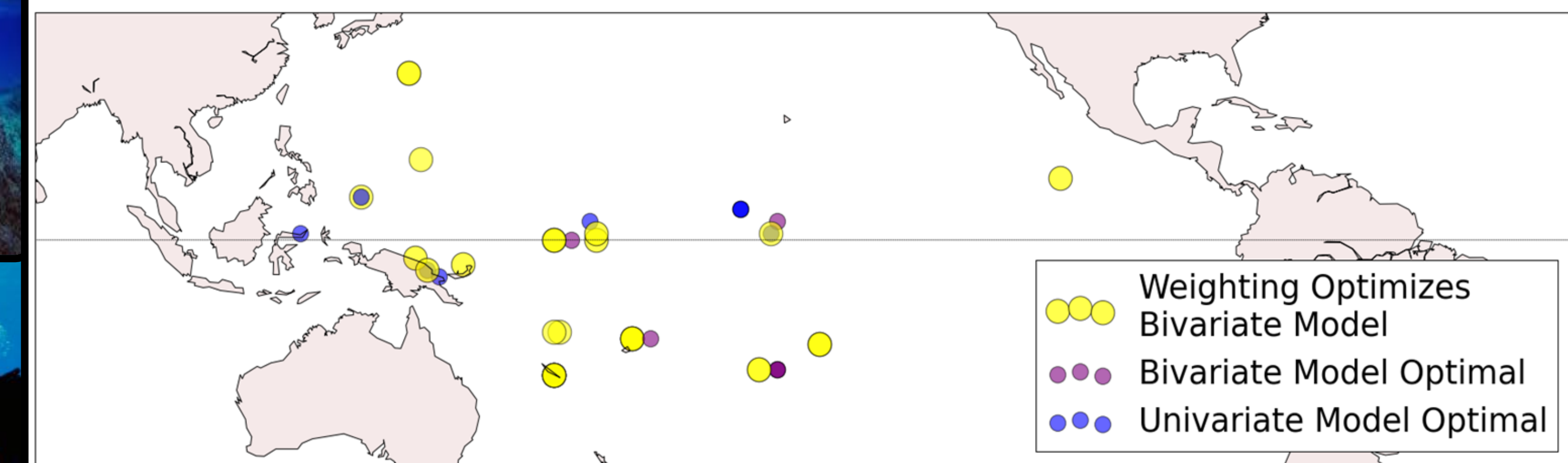


Figure 4 displays all coral sites. Yellow denotes sites at which the weighting methodology used optimizes the bivariate forward model's fit to the observed coral d18O. 32 out of the 45 total coral records are shown to be optimized by the weighting methodology. 6 records show that the bivariate model (50/50%) is the optimal relative contribution, and 7 show that the univariate model (100/0% SST or SSS) is the optimal contribution.

Table 1: Mean Strength of Proxy used in Last Millennium Reanalysis Data Assimilation (Denominator value; lower=more heavily weighted)

Ice Cores (n=103)	Tree Rings (n=429)	Corals (n=119)	Corals: Subset (BM) (n=45)
1.54	0.58	0.08	0.01

Table 1 tabulates values representing how much weight is given to each dataset in the LMR data assimilation. The values are based on the mean square error of the residuals by scaling the proxy to temperature with a linear regression, and taking the mean of the residuals² at each data point. Values are the mean from multiple datasets (n).

3 Results

-Identified site-specific contributions of SST/SSS to coral $\delta^{18}\text{O}$ that will improve future climate reconstruction efforts.

-Bivariate FM:

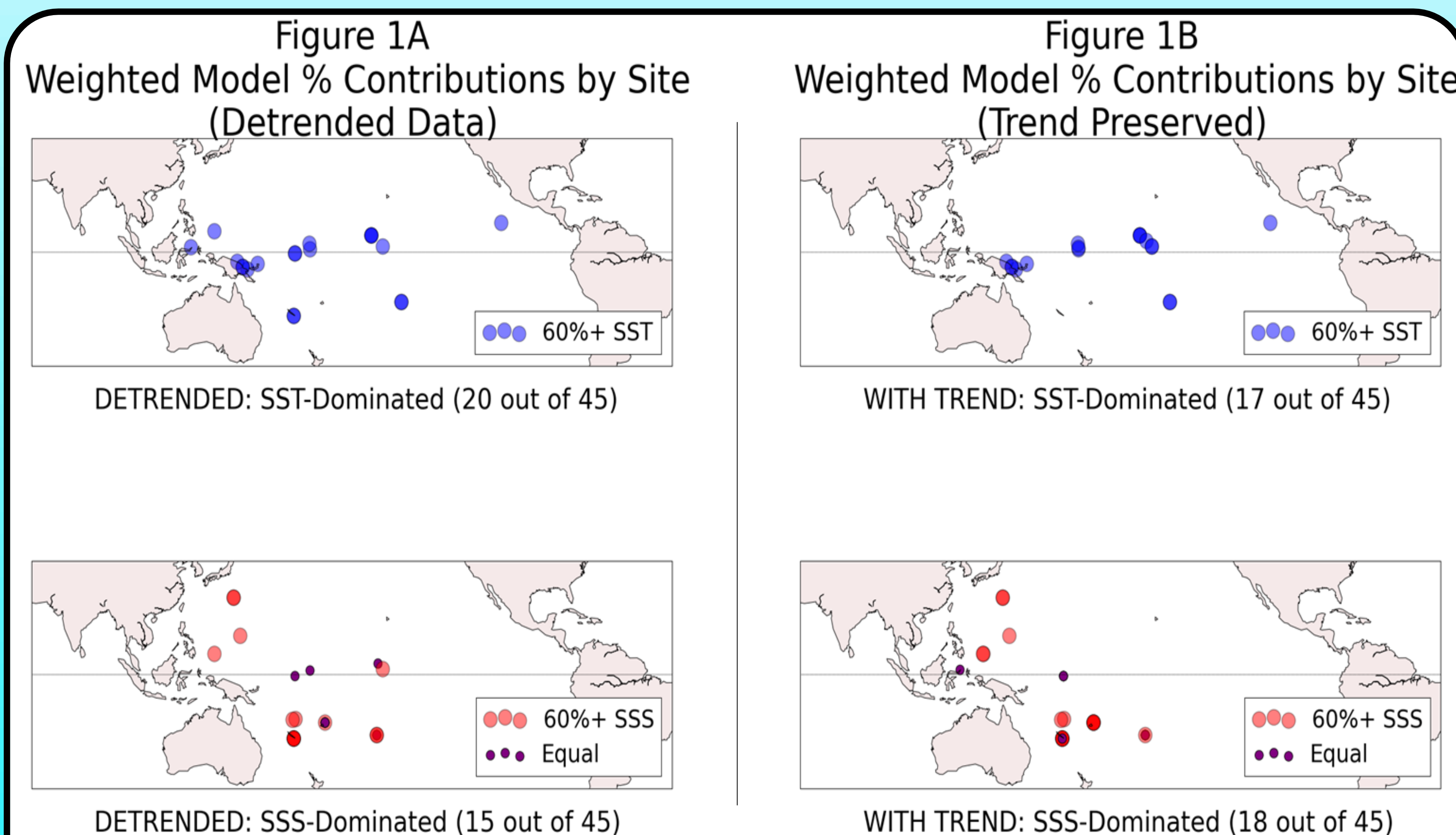
- Explains more $\delta^{18}\text{O}$ variance than univariate model at 78% of sites
- Explains twice as much $\delta^{18}\text{O}$ variance as the univariate model

-Weighted Bivariate FM:

- Optimizes bivariate model's fit to coral $\delta^{18}\text{O}$ at 73% of sites
 - Spatial structure of relative contributions is regionally consistent
- Bivariate forward model will improve LMR data assimilation results by strengthening the contributions of coral records to the analysis.
- Using a selected subset of forward-modelable coral records lowers archive-leading low mean error.

4 References

- [1] Thompson, D. M., et al. (2011), Comparison of observed and simulated tropical climate trends using a forward model of coral d18O, *Geophys. Res. Lett.*, 38, L14706, doi:10.1029/2011GL048224.
- [2] Gorman, M. K., et al. (2012), A coral-based reconstruction of sea surface salinity at Sabine Bank, Vanuatu from 1842 to 2007 CE, *Paleoceanography*, 27, PA3226, doi:10.1029/2012PA002302.
- [3] Moses, C. S., et al. (2006), Calibration of stable oxygen isotopes in *Siderastrea radians* (Cnidaria:Scleractinia): Implications for slow-growing corals, *Geochim. Geophys. Geosyst.*, 7, Q09007, doi:10.1029/2005GC001196.
- [4] LeGrande, A. N., and G. A. Schmidt (2006), Global gridded data set of the oxygen isotopic composition in seawater, *Geophys. Res. Lett.*, 33, L12604, doi:10.1029/2006GL026011.



Figures 1A and 1B demonstrate the spatial structure of the contributions of SST and SSS on coral d18O, based on results from the weighting method outlined above. The weights that were found to optimize the bivariate model were taken to be representative of the percent of the d18O signal that SST and SSS are responsible for, respectively. Figure 1A is the resultant spatial structure of the contributions of SST and SSS using detrended data. Figure 1B is the same methodology completed with the same datasets, without prior detrending. Figure 1C demonstrates a regionally consistent structure, with ITCZ corals being very temperature-dependent, whereas western subtropical and SPCZ corals are consistently more highly dominated by SSS variability. This could be representative of ENSO and its regional manifestation.

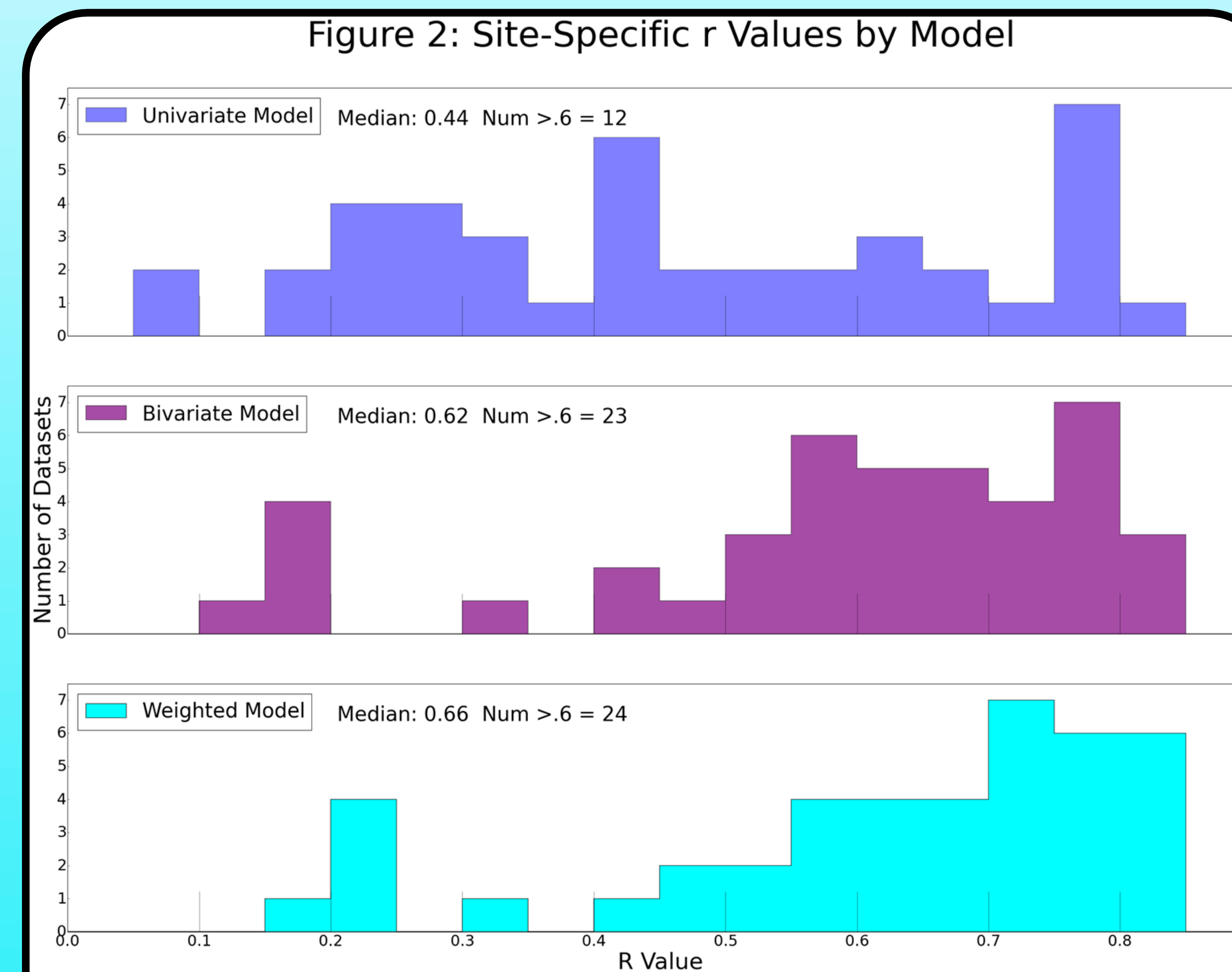


Figure 2 graphs the resultant r values from each respective model on a site-to-site basis. Each coral d18O record was forward-modeled using the univariate, bivariate, and weighted bivariate models, and then correlated to the coral d18O record. The calibration period varied by record depending upon the length of the period of overlap between the coral d18O time series, and the instrumental datasets that the forward models depended upon (instrumental limited to 1950-2011 based on Delcroix 2011). Normality tests verified that the Median values should be reported over the mean values. The number of datasets surpassing an r value of .6 are reported as well to demonstrate the strength of the bivariate model when a cutoff r or r² value is used.